SEC Petition Evaluation Report Addendum
Sandia National Laboratories – Livermore
Petition SEC-00059-Addendum

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Petition Administrative Summary

Petition Under Evaluation

Petition #	Petition Type	Petition B Qualification Date	DOE/AWE Facility Name
SEC-00059	83.13	October 4, 2006	Sandia National Laboratories–Livermore (SNL-L)

All X-ray technologists and materials scientists who worked in the X-ray Diffraction and Fluorescence Laboratory, Building 913-Room 113, Building 913-Room 128, and Building 941-Room 128 from December 1, 1967 through December 31, 1990.

Proposed Class Definition

All X-ray technologists and materials scientists who worked at Sandia National Laboratory-Livermore in the X-ray Diffraction and Fluorescence Laboratory, Building 913-Room 113, and Building 913-Room 128 from December 1, 1967 through December 31, 1990.

Related Petition Summary Information

SEC Petition Tracking #(s)	Petition Type	DOE/AWE Facility Name	Petition Status
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Related Evaluation Report Information

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Addendum to SEC-00059, Sandia National Laboratory – Livermore Evaluation Report

1.0 Introduction

At the May 2007 Advisory Board on Radiation and Worker Health (Board) meeting, concurrent with the presentation of the SEC-00059 Sandia National Laboratory-Livermore (SNL-L) Petition Evaluation Report (ER), the SEC-00059 petitioner submitted a letter (in his absence), dated April 25, 2007, describing what he believed were unresolved issues and unanswered questions in the SEC-00059 Sandia National Laboratory-Livermore ER. The Advisory Board suspended its review of the SEC-00059 ER pending NIOSH's review of the additional information provided in the SEC-00059 petitioner's letter. The petitioner has subsequently provided a personal letter and affidavit from a co-worker and co-petitioner dated July 16, 2007 (provided after a follow-up telephone call), to support the position that dose cannot be reconstructed with sufficient accuracy for the proposed class. This addendum to the SEC-00059 Sandia National Laboratory-Livermore ER presents the questions/issues raised by the SEC-00059 petitioner and provides a response to each issue.

2.0 Questions/Issues

The following summarizes the questions and issues presented in the April 25, 2007 letter provided by the SEC-00059 petitioner in response to the NIOSH findings presented in the SEC-00059 Evaluation Report:

1. Personnel monitoring records are unavailable

2. Directional nature of the X-ray radiation emitted from the Phillips units (radiation not emitted uniformly); X-ray beam location in relation to the personal dosimeter location (the dosimeter was worn either on the lapel or on the belt)

3. Workers devised makeshift shielding because the installed shield could not be used for oversized samples; potential for radiation leakage paths and potential for personnel exposures associated with radiation leakage from openings in the makeshift shielding

4. Unrecorded (or missing records related to) exposure incidents associated with the operation of the X-ray diffraction unit; specifically the differences between the 1978 undocumented exposure incident and the documented exposure incident in 1979

5. Ability to bound exposures; use of applicable correction factors as described in the Sandia National Laboratory-Livermore Site Profile and discussed in the SEC-00059 Evaluation Report

6. Differences in workload between the petitioner and the co-petitioner/class members and the impact of this difference on the ability to reconstruct dose

7. Use of sealed sources (as described in the SEC-00059 Evaluation Report) and the preparation of samples (using a mortar and pestle) at the petitioner's desk in the laboratory; exposures to toxic materials and non-radiological exposures; eating at the same location where samples were prepared

8. Statements made by two doctors indicate that exposures resulted in cancer for a petitioner; the inappropriateness/inadequacies associated with the risk models for radioactive material exposures; the determination of probability of causation

The following represents a summary of the applicable SEC questions and issues presented in the subsequently provided July 16, 2007 letter and affidavit forwarded by the SEC-00059 petitioners in response to the June 7, 2007 NIOSH follow-up telephone call regarding the SEC-00059 ER and April 25, 2007 letter:

9. Exposure data that was forwarded to the petitioner in June 2007 was information that the petitioner already had and was not pertinent to the work he performed in the X-ray diffraction lab

10. Concerns about attempting to reconstruct dose without ascertaining the predominant energy of the X-ray beam

11. Concern about the security badge location in relation to the dosimeter and shielding of the dosimeter by the security badge

12. The use primarily of a copper X-ray target (and sometimes iron – but not at the time of the major exposures)

13. The dosimeter in use at the time would not provide a valid account of the radiation dose from the X-ray diffraction unit; issues associated with the location of the dosimeters on the body (not worn on the lapel as they would have been in the way when trying to align samples)

14. The lack of specific monitoring data (either personal or area) prevents the adequate reconstruction of external X-ray dose for the proposed class; cannot use broad assumptions or "average" exposures to reconstruct dose

3.0 Question/Issue Resolution

NIOSH conducted a follow-up call on June 7, 2007 with the SEC-00059 petitioner to review the contents of their April 25, 2007 letter presented at the May 2007 Board meeting and to clarify the petitioner's issues. Described below are clarifications to the questions and issues presented in the petitioner's letter and NIOSH's response to each identified question and/or issue.

1. Personnel monitoring records are unavailable

The petitioner stated that his monitoring records are unavailable and that he has not been able to obtain his records from Sandia. The petitioner also indicated that he has submitted a Freedom of Information Act (FOIA) request for his personal monitoring data but has not received all of his data from that request. The petitioner stated that the lack of monitoring records from Sandia leads him to conclude that his records are unavailable.

NIOSH originally had some difficulty collecting the personal data for the entire proposed class period (December 1, 1967 through December 31, 1990), but that issue was remedied during the Sandia National Laboratory-Livermore data capture effort (four data capture trips were performed between February 2007 and May 2007). The primary issue leading up to the data capture effort was missing personnel external dosimetry data for the period prior to 1989. During the data capture, NIOSH identified and collected monitoring data representative of the entire proposed class period evaluated in the SEC-00059 Evaluation Report that included the previously missing pre-1989 external dosimetry data (the details and analysis of the available data are discussed in the SEC-00059 ER).

NIOSH informed the petitioner that he may submit a FOIA request to NIOSH to obtain the additional personnel monitoring records that NIOSH has obtained (those records identified as missing or otherwise unavailable by the petitioner). Based on NIOSH's documented telephone discussion with the petitioner and the information discussed above, NIOSH has concluded that no additional follow-up is required for this issue.

2. Directional nature of the X-ray radiation emitted from the Phillips units (radiation not emitted uniformly); X-ray beam location in relation to the personal dosimeter location (the dosimeter was worn either on the lapel or on the belt)

The petitioner stated that the X-ray radiation emitted from the Phillips X-ray diffraction units was directional in nature, noting that the radiation was not emitted uniformly. The SEC-00059 petitioner also discussed the general location of his dosimeter in relation to the X-ray beam. The petitioner stated that direct-beam exposures were not represented on the dosimeter because of the directional nature of the very small X-ray beam and the location of his dosimeter. The petitioner specifically noted that when the dosimeter was worn on the belt, no radiation would be detected because of the shielding provided by the diffraction unit table (the dosimeter would be below the level of the table top when worn on the beltline).

The petitioner described the X-ray diffraction unit operated by members of the proposed worker class evaluated in the SEC-00059 Evaluation Report as a "table-top" type of system. Direct beam exposures were those that originated from the shutter (described as a slit in the shutter) of the X-ray generator, and the scattered X-rays were those that came from the material being analyzed (during studies of crystalline structures for different elements). The petitioner stated that, based on the layout of the unit that was operated, the skin on the hands was the only part of the body that could incur a direct-beam exposure.

As discussed in the SEC-00059 ER and the SNL-L Site Profile, there were various dosimeters worn by the members of the SEC-00059 proposed worker class over the period evaluated in the ER. The changes in dosimeter-type corresponded to the changes in the radiological monitoring program over time. Considering the types of dosimeters used, the exposure geometry, and applicable energy response/radiation detection capabilities, NIOSH believes that the dosimeters used at SNL-L would have been best served in the capacity of recording whole-body exposures to uniformly emitted radiation emanating from the radioactive materials handled in the laboratory. As these dosimeters are most commonly used to collect data on whole-body external radiation exposures, NIOSH agrees with the petitioner that these dosimeters would not perform well (or efficiently) in the capacity of measuring/detecting X-ray exposures from the diffraction unit; this is because the X-ray beams associated with the diffraction unit are very small and focused, and the scattered (or diffracted beam) X-ray radiation associated with the diffraction unit would be a very low-energy range. At least one personal exposure incident associated with the X-ray diffraction unit was evaluated by Sandia National Laboratory-Livermore in a documented incident report. The analysis of personnel direct beam X-ray exposures or diffracted/scattered X-ray radiation exposures associated with the operation of the X-ray diffraction units are described in Section 4.0 of this ER Addendum.

In response to this issue, NIOSH will use the applicable personnel dosimetry data to reconstruct the dose from exposures to radioactive materials in the laboratory and apply the methods generally described in the direct beam and scattered radiation discussion (Section 4.0) as a bounding approach to reconstructing X-ray radiation exposures for the proposed class evaluated in the SEC-00059 Evaluation Report.

3. Workers devised makeshift shielding because the installed shield could not be used for oversized samples; potential for radiation leakage paths and potential for personnel exposures associated with radiation leakage from openings in the makeshift shielding

The SEC-00059 petitioner stated that in some cases it was necessary to devise makeshift shielding because the permanently installed shield could not be used for oversized samples (oversized samples prevented closing the permanently installed Lucite cover plate). The petitioner discussed the potential radiation leakage paths and the potential for personnel exposures associated with radiation leakage from openings in the makeshift shielding. The petitioner stated that the makeshift shielding was installed to serve two purposes: 1) serve as a guard to prevent direct access to the X-ray beam (serving as a physical shield or guard) and 2) protect personnel from radiation exposures (serving as radiation shielding). The makeshift shielding was constructed using Lucite material wrapped with lead tape. The petitioner stated that there were significant gaps in the makeshift shielding and that it did not adequately cover the X-ray diffraction chamber. He specifically mentioned a gap associated with the diffractometer (2" wide by approximately 7" long). The diffractometer rotated 180^{o} to measure diffraction angles and left a moving opening in the shielding. There was also concern expressed by the petitioner regarding the potential for X-rays to be emitted, or to leak, from the X-ray generator tower (no specific manner of leakage described, although in the petitioner's opinion, the generator tower had four ports through which

X-ray radiation leakage could occur). The petitioner contends that there were unmonitored or inadequately monitored personnel exposures associated with the radiation that was scattered after impinging on the target or sample in the diffraction chamber, and then leaking out of the chamber from one of the previously described gaps in the shielding.

The SEC-00059 petitioner discussed work on a project associated with the performance of diffraction analysis on "every element in the periodic table." That project was associated with the assembly of a standards book on the elements. He said that these elements were provided as nuggets that had to be retrieved from a safe and ground up into powders (using a mortar and pestle) prior to placement into glass capillary tubes for analysis. The petitioner stated that the sample preparation was performed at his desk, which is the same location at which he ate his lunch.

The petitioner also stated that the X-ray diffraction unit sat on a 2-foot square table and that the distance from the sample to the unit operator's body was approximately 1-2 feet (noting that fingers and hands would be closest to the X-ray beam; however, the petitioner noted that personnel did not normally receive direct beam hand exposures). He described the operations of the X-ray diffraction unit and indicated that he operated the X-ray diffraction at 40 kV and 20 mA settings. He also stated that all of the equipment associated with the diffraction unit was contained within an enclosure behind the in-place Lucite cover/shield. The petitioner discussed taking radiation measurements of the scattered radiation that leaked from the chamber (as previously discussed) using a G-M tube (Geiger-Mueller radiation detector).

The petitioner did indicate that safety interlocks were associated with the operation of the X-ray diffraction unit. Specifically, he indicated that there was a mechanical interlock associated with the Lucite cover/shield and a safety interlock that would light up when the X-ray diffraction unit was operating. The petitioner indicated that it was possible for the mechanical interlock to fail, noting that this was the cause of his 1978 exposure incident. He stated that the aforementioned safety interlock was installed on the unit as a result of his exposure incident. However, the petitioner was not certain if this interlock was associated with the diffractometer or with the X-ray generator unit/shutter.

NIOSH has reviewed the available site-level procedures, site-level directives, and regulations governing the operation of the type of X-ray diffraction unit in place at Sandia National Laboratory-Livermore. In cases where the makeshift shielding (Lucite wrapped in lead tape) had to be used, NIOSH agrees that diffracted/scattered X-ray radiation could leak out of the improvised enclosure from gaps or openings in the shielding. NIOSH also concurs that there is a potential for this leaked X-ray radiation to result in some level of exposure to the X-ray diffraction unit operator. The analysis of the potential exposures from diffracted/scattered X-rays is included in Section 4.0 of this ER Addendum. However, in comparison to the potential X-ray radiation exposures associated with the operation of the diffraction unit with makeshift shielding installed, NIOSH believes that the potential for direct beam and scattered X-ray radiation exposures was greatly reduced when the system was operated as designed, that is, using the in-place shield and in accordance with the operating procedures of the time (assuming correctly operating system safety interlocks and minimal gaps in the in-place Lucite shield integral to the unit).

As it relates to the petitioner's concern about X-ray diffraction analysis of every element in the periodic table, NIOSH has not confirmed (based on the evidence and information currently available for the proposed class) that there were actual radiological exposures, from the elements being analyzed, associated with that work. The petitioner indicated that this project was associated with the assembly of a standards book on the elements. This radiological dose reconstruction program does not include evaluations of exposures, or potential exposures, to non-radioactive elements.

In response to this issue, the information provided by the petitioner regarding the layout and potential exposure geometries associated with the operation of the X-ray diffraction unit can be used by NIOSH in the corresponding radiological assessment of the potential exposures during the operation of the unit and assignment of personnel doses. NIOSH will apply the methods generally described in the direct beam and scattered radiation discussion sections (Section 4.0) as a bounding approach to reconstructing X-ray radiation exposures for the proposed class evaluated in the report. Based on the information gathered during this evaluation, NIOSH has concluded that the approach described in Section 4.2 will be applied as a bounding approach in cases where class members indicate that they operated the X-ray diffraction unit with or without makeshift shielding over the diffraction chamber (or similar discussions).

4. Unrecorded (or missing records related to) exposure incidents associated with the operation of the X-ray diffraction unit; specifically the differences between the 1978 undocumented exposure incident and the documented exposure incident in 1979

The petitioner stated that his 1978 exposure incident was more severe than his documented 1979 exposure incident. The petitioner stated that in the minutes leading up to his 1978 exposure, he had been working on the X-ray diffraction unit (approximately 20-30 minutes) and had thought that the unit was de-energized (X-ray beam off). He indicated that while placing some phosphor material in the location of the sample, the phosphor lit up when the material crossed the beam (indicating that the phosphor gives off light when exposed to radiation/a radiation beam). The petitioner stated that he likely received a 5-10 second exposure before he realized that the beam unit was energized (X-ray beam on) and then secured his activities.

The petitioner indicated that following the 1978 incident a site health physicist performed a post-exposure follow-up. The petitioner stated that he had reddening of the skin on his fingers (as a result of the direct beam exposure) and that he was required to report to medical (more than once) for follow-up medical exams of the exposed skin. The petitioner believes that while there were probably records of this incident, the site managed records poorly, which may be the reason that the records are unavailable.

NIOSH's original evaluation, documented in the SEC-00059 Evaluation Report, was based on the original Form B petition and associated supporting documentation provided by the petitioner. The petitioner subsequently provided new information in a letter provided in response to NIOSH's SEC Evaluation Report. NIOSH re-examined the SEC-00059 evaluation based on the new

information provided in the petitioner's letter and the clarifying information provided by the petitioner during NIOSH's follow-up telephone call.

In response to this issue, NIOSH has revised the approach described in its original SEC-00059 Evaluation Report and will apply the methods generally described in the direct beam discussion, in Section 4.0, as a bounding approach to reconstructing X-ray radiation exposures for the proposed class evaluated in the report. Although the defined approach has been revised, NIOSH maintains its conclusion that it has sufficient information to bound the dose for the proposed worker class defined in this report.

5. Ability to bound exposures; use of applicable correction factors as described in the Sandia National Laboratory-Livermore Site Profile and discussed the SEC-00059 Evaluation Report

The petitioner discussed the SEC-00059 Evaluation Report statements indicating NIOSH's belief that doses can be estimated with sufficient accuracy. The petitioner also mentioned the report discussion of correction factors, etc. The petitioner expressed concern regarding NIOSH's ability to specifically reconstruct his dose. He also expressed concern over the impact of including the other two individuals in the proposed class in this petition and believed that at least one of the other's records may have some negative impact on the overall evaluation. The petitioner indicated that he may have some additional information to provide on this subject (from a doctor).

As performed by NIOSH, the process of evaluating a SEC Form B petition includes reviewing the information available for the proposed class and does not make any determinations concerning the feasibility of dose reconstruction that necessarily apply to any individual energy employee who might require a dose reconstruction from NIOSH. Under EEOICPA and the Special Exposure Cohort Rule, if NIOSH can demonstrate the ability to complete radiation dose reconstruction with sufficient accuracy in support of a probability of causation (POC) determination for a proposed worker class, the resulting recommendation in the associated evaluation report will be not to include the proposed class in the SEC. As it is the intent of the EEOICPA program to appropriately determine the POC for individual claims, and not to determine the exact dose for every member of the proposed class, NIOSH incorporates efficiency methods (including the use of correction factors and calculations which always err in favor of the claimant) for EEOICPA dose reconstructions.

NIOSH has concluded that in addition to evaluating radioactive material exposures at Sandia National Laboratory-Livermore as discussed in *SNL Site Profile-Technical Basis Document* (ORAUT-TKBS-0053), NIOSH will apply the methods generally described in the direct beam and scattered radiation discussion in Section 4.0 as a bounding approach to reconstructing X-ray radiation exposures for the proposed class evaluated in the report.

6. Difference in workload between the petitioner and the co-petitioner/class members and the impact of this difference on the ability to reconstruct dose

The petitioner indicated that he turned the laboratory operations over to another diffraction unit operator (who is also a co-petitioner) before he proceeded to perform different work in another area of Sandia National Laboratory-Livermore. The petitioner indicated that the operator, to whom he turned his work over, operated the diffraction unit much less frequently (did not perform the volume of work). Therefore, in the petitioner's opinion, the petitioner's exposures would be higher than the co-petitioner's exposures. The petitioner stated that he is currently on full disability and that the co-petitioner who replaced him in the X-ray diffraction laboratory no longer speaks to him regarding the Special Exposure Cohort petition.

The petitioner also stated that he completed an X-ray diffraction standards table (analyzing all elements in the periodic table) and that the other operator did not experience these exposures. The work associated with the standards table is reviewed further in the following discussion item (item 7).

NIOSH has concluded that the variation in workload between individuals working in the lab does not prevent reconstructing dose for the proposed class. The evaluation of exposures and associated doses to proposed worker class members can be adjusted according to work schedules and exposure times/periods. As it concerns the work with elements of the periodic table, NIOSH has no indication of potential exposures to radioactive materials during this work. Therefore, based on the information included in the SNL Site Profile-Technical Basis Document for evaluating radioactive material exposures, and the methods generally described in Section 4.0, NIOSH can establish a bounding approach to reconstructing radiation exposures for the proposed class evaluated in the report.

7. Use of sealed sources (as described in the SEC-00059 Evaluation Report) and the preparation of samples (using a mortar and pestle) at the petitioner's desk in the laboratory; exposures to toxic materials and non-radiological exposures; eating at the same location where samples were prepared

The petitioner stated that he performed X-ray diffraction analysis on the elements listed in the periodic table while in the process of developing an X-ray diffraction standards table. He explained that he would obtain a sample of an element and grind it using a mortar and pestle. The sample was then placed in a capillary tube. He indicated that he performed this sample preparation work at his desk, where he also ate his lunch. The petitioner also discussed exposure to toxic materials and non-radiological exposures.

The petitioner indicated that he understood that non-radiological exposures were covered under subpart E of EEOICPA. He stated that he had applied under subpart E two different times but experienced some difficulty under that process (he had been informed by DOL that he had to provide employment verification again with his subpart E application).

NIOSH has concluded that although eating at the same location where samples are prepared is not considered a good radiological practice, this does not preclude NIOSH's ability to bound dose for members of the proposed class (based on the availability of bioassay data). As previously discussed, non-radiological exposures are not covered under this radiological dose reconstruction program. Therefore, based on available internal and external personnel monitoring data, the information included in the SNL Site Profile-Technical Basis Document for evaluating radioactive material exposures, and the methods generally described in Section 4.0, NIOSH can establish a bounding approach to reconstructing radiation exposures for the proposed class evaluated in the report.

8. Statements made by two doctors indicate that exposures resulted in cancer for a petitioner; the inappropriateness/inadequacies associated with the risk models for radioactive material exposures; the determination of probability of causation

The petitioner discussed statements made by two doctors regarding the cause of the primary petitioner's cancer, the risk models associated with radioactive material exposures, and the determination of probability of causation.

NIOSH has concluded that the petitioner's issues regarding this particular item are specific to the performance of his individual dose reconstruction. NIOSH informed the petitioner that specific claimant issues related to performance/result of an individual dose reconstruction are outside the scope of the SEC process. Based on available internal and external personnel monitoring data, the information included in the SNL Site Profile-Technical Basis Document for evaluating radioactive material exposures, and the methods generally described in Section 4.0, NIOSH can establish a bounding approach to reconstructing radiation exposures for the proposed class evaluated in the SEC-00059 SNL-L Evaluation Report.

The petitioner also provided a letter and affidavit, dated July 16, 2007, in response to the June 7, 2007 telephone call. Included below are the questions and/or issues presented in the letter and affidavit and NIOSH's response to each identified question and/or issue.

9. Exposure data that was forwarded to the petitioner in June 2007 was information that the petitioner already had and was not pertinent to work he performed in the X-ray diffraction lab

The petitioner has stated that the information provided by NIOSH, as a result of the petitioner's FOIA request, does not include personal monitoring data for the period which the petitioner operated the X-ray diffraction unit. In response, NIOSH did provide the most recently linked personnel monitoring records (that have been identified as containing claimant monitoring data and linked to the applicable claimants in the NIOSH OCAS Claims Tracking system (NOCTS) to the petitioner. Although the data that were provided to the petitioner did not contain data in the era of concern for the petitioner, NIOSH does have access to data for that era (including data for

the petitioner that has not yet been linked to his individual claim). Therefore, NIOSH does not agree with the conclusion of the petitioner – that there is no data available applicable to his operation of the X-ray diffraction period. This issue however, relates more specifically to the individual claim associated with the SEC petitioner and not the SEC evaluation that addresses NIOSH's ability to bound doses for the proposed SNL-L proposed worker class.

10. Concerns about attempting to reconstruct dose without ascertaining the predominant energy of the X-ray beam

The petitioner has indicated that he believes it is not possible to evaluate the dose for personnel who operated the X-ray diffraction units without ascertaining the predominant energy of the X-ray beam. Based on the review and analysis of the applicable information associated with the operation of the X-ray diffraction unit, NIOSH has ascertained the predominant energy of the X-ray beam and applied it in the evaluation of the potential exposures to individuals operating the equipment (as discussed in the analysis included in Section 4.0). NIOSH has included an analysis in this Evaluation Report Addendum that accounts for the X-ray beam energy for the purpose of providing a bounding dose estimate for the proposed worker class defined in this petition.

11. Concern about the security badge location in relation to the dosimeter and shielding of the dosimeter by the security badge

The petitioner has expressed a concern that the security badge location, in front of the dosimeter badge, prevents obtaining an accurate dose reading because of the shielding effect of the security badge on the dosimeter. Based on its review of the related information, NIOSH finds that any radiation shielding effects that may have occurred as a result of the security badge being located in front of the dosimeter, would be limited to shallow radiation dose components (*i.e.*, low energy X-rays in this case). In any case, the alternative dose reconstruction method discussed in this Evaluation Report Addendum, included in Section 4.0, has eliminated the need to further evaluate this shielding effect from the operation of the X-ray diffraction unit. Specifically, the determination of personnel X-ray exposures and dose is a result of the source term evaluation and does not attempt to incorporate dosimeter corrections/adjustments.

NIOSH has concluded that for the purpose of providing a bounding dose estimate for the proposed worker class defined in this petition, the alternative dose reconstruction method discussed in this Evaluation Report Addendum, included in Section 4.0, has eliminated the need to further evaluate this shielding effect from the operation of the X-ray diffraction unit. Specifically, the determination of personnel X-ray exposures and dose is a result of the source term evaluation and does not attempt to incorporate dosimeter corrections/adjustments.

12. The use primarily of a copper X-ray target (and sometimes iron – but not at the time of the major exposures)

The petitioner has indicated that copper (and sometime iron) was the primary target used in the X-ray diffraction units applicable to the SEC petition evaluation. As included in Section 4.0, NIOSH's evaluation of potential exposures to individuals operating the X-ray diffraction unit considers copper as the primary target for the unit. Consideration of other target material, such as iron, is possible based on the information included in the applicable X-ray diffraction reference.

13. The dosimeter in use at the time would not provide a valid account of the radiation dose from the X-ray diffraction unit; issues associated with the location of the dosimeters on the body (not worn on the torso/lapel as they would have been in the way when trying to align samples)

The petitioner has expressed a concern about the validity of the radiation dosimeter readings, as they relate to personnel exposures to X-rays from the diffraction unit and the location of the security badge in relation to the exposure source (in some cases worn on the waistline, instead of the torso/lapel, which was below the table where the X-ray diffraction unit was located). NIOSH concurs that the dosimeters would likely not provide an accurate account of the external X-ray dose for those individuals and that dosimeter exposure geometry issues (wearing the dosimeter on locations other than the torso/lapel) compound issues associated with evaluating exposures and determining personnel shallow/X-ray dose from dosimeter readings. However, the methodology included in Section 4.0 provides the method for evaluating X-ray dose for individuals operating the diffraction units using source term information instead of the potentially inaccurate dosimeter results.

NIOSH has concluded that Section 4.0 provides a bounding dose estimate method for evaluating X-ray dose for individuals operating the diffraction units using source term information instead of the potentially inaccurate dosimeter results.

14. The lack of specific monitoring data (either personal or area) prevents the adequate reconstruction of external X-ray dose for the proposed class; cannot use broad assumptions or "average" exposures to reconstruct dose

The petitioner has stated that there is a lack of monitoring data that prevents the adequate reconstruction of personnel dose and that it is not appropriate to apply broad assumptions to reconstruct dose for members of the proposed class defined in this petition. However, NIOSH does have access to personal monitoring data (bioassay and dosimeter results) and source term information applicable to the petition proposed class. The assumptions that have been applied are specific to the proposed class that worked in the areas defined in the proposed class definition. Therefore, NIOSH does not agree with the conclusion of the petitioner.

4.0 X-ray Diffraction Unit Direct Beam and Diffracted Beam Exposures

The analysis described below is based on specific exposure scenario information provided by the SEC-00059 petitioner during his telephone call with NIOSH to discuss his letter. The two exposure scenarios evaluated in this section were identified as scenarios requiring further analysis and explanation for the applicable dose reconstruction method to be applied to the SEC-00059 proposed worker class.

4.1 Direct X-ray Diffraction Beam Calculation to Hands

Approach:

1. The range of dose that would result in skin effects varying from skin reddening to skin blistering and/or desquamation, but would not result in tissue necrosis that could require finger amputation, is approximately 15Gy to 40Gy (CDC, 2005; Gusev, 2001, pages 223-240). These values can be applied to bound dose to hands receiving direct X-ray diffraction beam exposures.

2. Use shallow dose values reported from 1979 accident report at Sandia Livermore diffraction unit (Lovell 1980, page 5).

a. Shallow: 30 rads / 20 sec (operating at 25 kVp, 1 mA)

3. Normalize to 40 kVp and 20 mA (X-ray diffraction unit operating values as stated in the SEC petition applicable to the petitioner-identified 1978 direct exposure incident). Normalization is based on relationship in Lubenau, 1971 (U. S. Department of Health Education and Welfare, 1971, page 191) which is referenced in ICRU Report 1b, 1962.

a. Exposure rate in R/sec = $[(50 \times kVp \times mA)/(cm)^2][Z/74]$ where Z is atomic number of tube target. This relationship implies direct proportionality between intensity and kVp and mA. These relationships are compared to measured values in Table 1 of Lubenau, 1971 (U. S. Department of Health Education and Welfare, 1971, page 192).

b. The relationship between intensity and kVp and mA from Lubenau, 1971 was used since it applies to X-ray diffraction energies. The proportionality between intensity and $kVp^{1.7}$ mentioned in OTIB-006, *Technical Information Bulletin: Dose Reconstruction from Occupationally Related Diagnostic X-Ray Procedures*, only holds true for X-ray energies greater than approximately 80 kVp.

c. Shallow dose (at 7 mg/cm^2) is based on the Lubenau proportionality relationship: 30 rad/20 sec * 3600 sec/hour * 40/25 * 20 /1 = 1.7 E05 rad/hour or 1.7 E03 Gy/hour.

4. Amount of time hands could have been in the direct beam for an acute exposure without having hand tissue necrosis:

a. Lower end of dose range without resulting in tissue necrosis requiring amputation:
15 Gy/1.7 E03 Gy/hr = 8.8 E-03 hours or 32 sec

b. Upper end of dose range without resulting in tissue necrosis requiring amputation:
40 Gy/1.7 E03 Gy/hr = 2.4 E-03 hours or 1.4 min

c. Range of time hands could have been in the X-ray diffraction beam without tissue necrosis is approximately 0 seconds to 1.4 minutes

4.2 Organ Dose from Diffracted X-Ray Beam Calculation

Approach:

Estimate organ dose from diffracted X-ray beam, correcting for beam size and organ depth. Based on the information gathered during this evaluation, NIOSH has concluded that the approach described in this section will be applied as a bounding approach in cases where class member indicated that they operated the X-ray diffraction unit with or without makeshift shielding over the diffraction chamber (or similar discussions).

Assumptions:

1. Worker is seated at bench top, which supports the XRD machine, for 20 hours/week.

2. Only the upper, anterior portion of the body is exposed in this geometry (about 25% of total body surface area).

3. Diffracted beam from copper target contains primarily characteristic X-rays from copper (see spectral graph in Kehl, 1971 (U. S. Department of Health Education and Welfare, 1971, page 21) and Rudman, 1971 (U. S. Department of Health Education and Welfare, 1971, page 83).

4. Fraction of time that tissue is exposed to diffracted beam is proportional to the ratio of the diffracted beam size (area) to the area potentially exposed (front upper torso).

Calculation:

1. Use exposure rate value reported from 1979 accident report for Sandia Livermore Diffraction unit (Lovell 1980, page 5).

a. 1.7 R/sec = 6.12 E 3 R/hour (operating at 25 kVp, 1 mA)

2. Normalize to 40 kVp and 20 mA (stated in submission)

a. 6.12 E 3 R/hour * 40/25 * 20 /1 = 1.96 E05 R/hour

3. Diffracted beam fraction of 3.3 E-06 derived from data from Kehl, 1971 (U. S. Department of Health Education and Welfare, 1971, page 37).

4. Diffracted beam dose rate at bench top (1 foot) no shielding or attenuation by air.

a. 1.96 E05 R/hour * 3.3 E-06 = 0.650 R/hour

5. Diffracted beam exposure rate corrected for duration of time spent in beam.

a. Assume 25% of total surface skin area is potentially exposed and a small beam cross-section of about 10 cm^2 at bench top 30 cm from the exit port (0.01 cm^2 at the exit port) (U. S. Department of Health Education and Welfare, 1971, page 82).

b. Potentially exposed skin area (ICRP 23) = 1.8 m^2 * 0.25 * 1 E04 cm^2/m^2 = 4.5 E03 cm^2

c. Exposure rate to any one 10 cm^2 area of the upper front torso: 0.650 R/hour /4.5 E03 cm^2 * 10 cm^2 = 0.0014 R/hour

6. Organ Dose (excluding lymphatic system and skin) = 0.0014 R/hour * Organ Dose Correction Factor (ODCF) (OCAS-IG-001, Rev. 02)

Example of organ dose (assuming exposure of 20 hour/week, 50 weeks/year)			
Organ	**Exposure Rate (R/hour)**	**ODCF (rem/R)**	**Organ Dose (rem/year)**
Bladder	0.0014	0.0080	0.012 rem
Thymus	0.0014	0.0145	0.021 rem

7. Organ Dose (lymphatic system from 9 keV photons)

a. A review of locations of lymph node chains (Goans, 2007) determined that the most claimant-favorable set would be the infraclavicular, scalene, and epitrochlear (around elbow) at a depth of 5 mm (Goans, 2007).

b. Exposure rate at 5 mm = Exposure * $e^{-(5.27)(1.06\ g/cm\text{^}3)(0.5\ cm)}$

c. Exposure rate at 5 mm = 0.0014 R/hour * 0.06 = 0.0001 R/hour

d. Dose to lymph node = 0.877 * (Exposure) * (μ/ρ)med / (μ/ρ)air

e. Dose to lymph node = 0.877 * 5.27 / 4.99 * 0.0001 R/hr = 0.0001 rad/hour

f. Annual dose (1000 hour/year) = 0.080 rad

8. Organ Dose (skin from 9 keV photons)

a. Exposure rate at 0.07 mm = Exposure * $e^{-(5.27)(1.06\ g/cm^3)(0.007\ cm)}$

b. Exposure rate at 0.07 mm = 0.0014 R/hour * 0.96 = 0.0014 R/hour

c. Dose to skin = 0.877 * (Exposure) * (μ/ρ)med / (μ/ρ)air

d. Dose to skin = 0.877 * 0.0014 R/hour * 5.27 / 4.99 = 0.0013 rad/hour

e. Annual dose (1000 hr/yr) = 1.25 rad

5.0 ER Revisions/Changes Based on the Addendum to the ER

Based on NIOSH's review of the petitioner's letter provided in response to the SEC-00059 Sandia National Laboratory-Livermore Evaluation Report and the additional information provided by the SEC-00059 petitioner, NIOSH reviewed and revised the following statements/sections of the SEC00059 evaluation report. Corrections to the Evaluation Report statements read as follows:
NOTE: The changes suggested in this SEC-00059 Evaluation Report Addendum do not result in any recommended changes to the SEC-00059 Evaluation Report feasibility findings.

Section 7.3.1.4 Dosimetry Records

External dosimetry records are available for the covered period applicable to this petition, SEC-00059 Evaluation Report, and SEC00059 Addendum. The data are arranged by employee Social Security number and provide penetrating and non-penetrating radiation dose information from which gamma, beta, and neutron doses are inferred. Specific documentation indicates extremity monitoring was performed at SNL-L during the timeframe evaluated in this report and addendum; however, no specific extremity monitoring data have been identified for this proposed worker class. Information contained in available personnel monitoring records also indicate that extremity monitoring was performed (and/or recorded) starting in the 1989-1990 time period (ORAUT-TKBS-0053; SNL, no date; SNL, 1990).

A dose reconstruction was performed by SNL-L for an X-ray technician who was involved in an incident involving a shutter malfunction (Lovell, 1980). These data, coupled with the evaluation of the direct beam and scattered beam exposures, can be used to supplement the personnel dosimetry records for other exposure incidents, such as the claimed 1978 incident where a second petitioner indicated exposures to a separate but similar incident.

Section 7.3.4.2 Incidents

There were two incidents, one in 1978 (claimed by the petitioner with no supporting documentation provided) and another in 1979 (supporting documentation provided), involving the mechanical failure or the bypassing of a shutter in an X-ray Diffractometer. A dose reconstruction and report are

available for the 1979 incident (Lovell, 1980). In the first incident, the safety interlocks failed while calibrating a refractometer and thus, did not prevent operation of the system. As a result, the operator received an accidental elevated exposure of ionizing radiation. In the second incident, the shutter was removed during operation, which allowed a full intensity beam without shielding. NIOSH has considered all of the relevant unit operational information and exposure information and has developed a method to bound the potential exposures associated with the operation of the X-ray diffraction unit, which can be used to reconstruct the dose for the 1978 alleged exposure incident (or similar exposure scenarios).

Section 7.4.1.1 Two Specific Incidents: 1978 and 1979 Incidents

SEC-00059: *The basis for proposing that one or more unmonitored, unrecorded, or inadequately monitored exposure incidents occurred can be exemplified by citing two incidents that occurred during the 23 years that this laboratory was operated.*

The petition refers to two incidents: one in 1978 and one in 1979. Both incidents involved a problem with an interlock associated with the operation of the X-ray diffraction unit, while working with the Norelco Diffraction X-ray Generator (the same unit was in place over that time period). The petitioner has provided evidence of a potential unmonitored exposure, as there are currently no available personal or area monitoring data for the first (1978) exposure incident.

Information contained in the incident report for the second incident (Lovell, 1980) and obtained from interviews with former employees (Nichols, 2007) indicates that the circumstances surrounding the two incidents are similar. NIOSH has considered all of the relevant unit operational information and exposure information and has developed a method to bound the potential exposures associated with the operation of the X-ray diffraction unit, which can be used to reconstruct the dose for the 1978 alleged exposure incident (or similar exposure scenarios).

Section 7.4.1.2 Dosimeter Placement

SEC-00059: *These exposures are based on unmonitored, unrecorded, and inadequately monitored exposures. For security purposes, employees were required to wear their dosimeters behind their security badge which effectively blocked a significant amount of the radiation that was being emitted about the room and exposing those working in the vicinity.*

Based on its review of the Sandia National Laboratory-Livermore program documentation available in the SRDB, NIOSH has determined that the dosimeter was part of the security badge and may have detected exposure in the same manner as a stand-alone dosimeter. This issue has no effect on the ability to detect gamma radiation associated with the exposure to radioactive material in the laboratory. As discussed in Section 5.0 above, NIOSH can use the available information associated with the X-ray diffraction unit and documented personnel exposures associated with that unit to evaluate potential X-ray dose for personnel that operated the unit or worked in the laboratory. Therefore, NIOSH has concluded that radiation dose can be bounded for the applicable exposure scenarios that existed at SNL-L for the proposed time period evaluated for the SEC-00059 petition.

6.0 References

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SNL, 1990, *Radiation Safety Procedures for the Use of X-ray Equipment Located in Building 913, Room 128E*, Revision B, Standard Operating Procedure; Sandia National Laboratory (SNL); August 1990; SRDB Ref ID: 28172

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